Practical Approaches to 3D Cadastre Implementation: Database Schemas and Exchange Formats

Javad Shahidinejad

A/Prof Mohsen Kalantari

Prof Abbas Rajabifard

12th International FIG Land Administration Domain Model & 3D Land Administration Workshop

24-26 September 2024, Kuching, Malaysia

THE UNIVERSITY OF MELBOURNE

CSDILA
THE CENTRE FOR SPATIAL DATA INFRASTRUCTURES & LAND ADMINISTRATION
Est. 2001

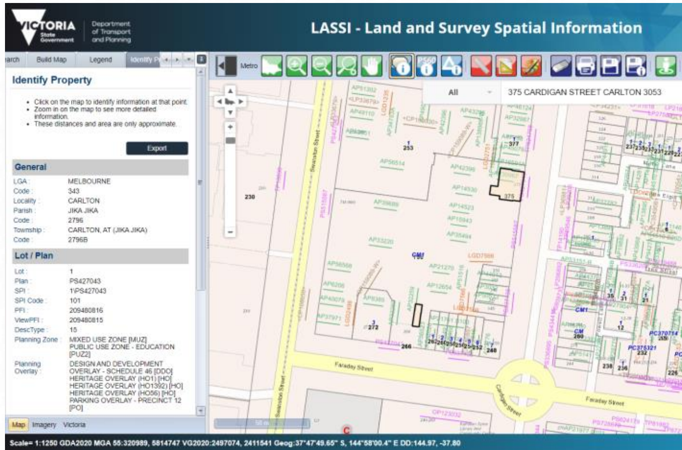
CONTENTS

INTRODUCTION

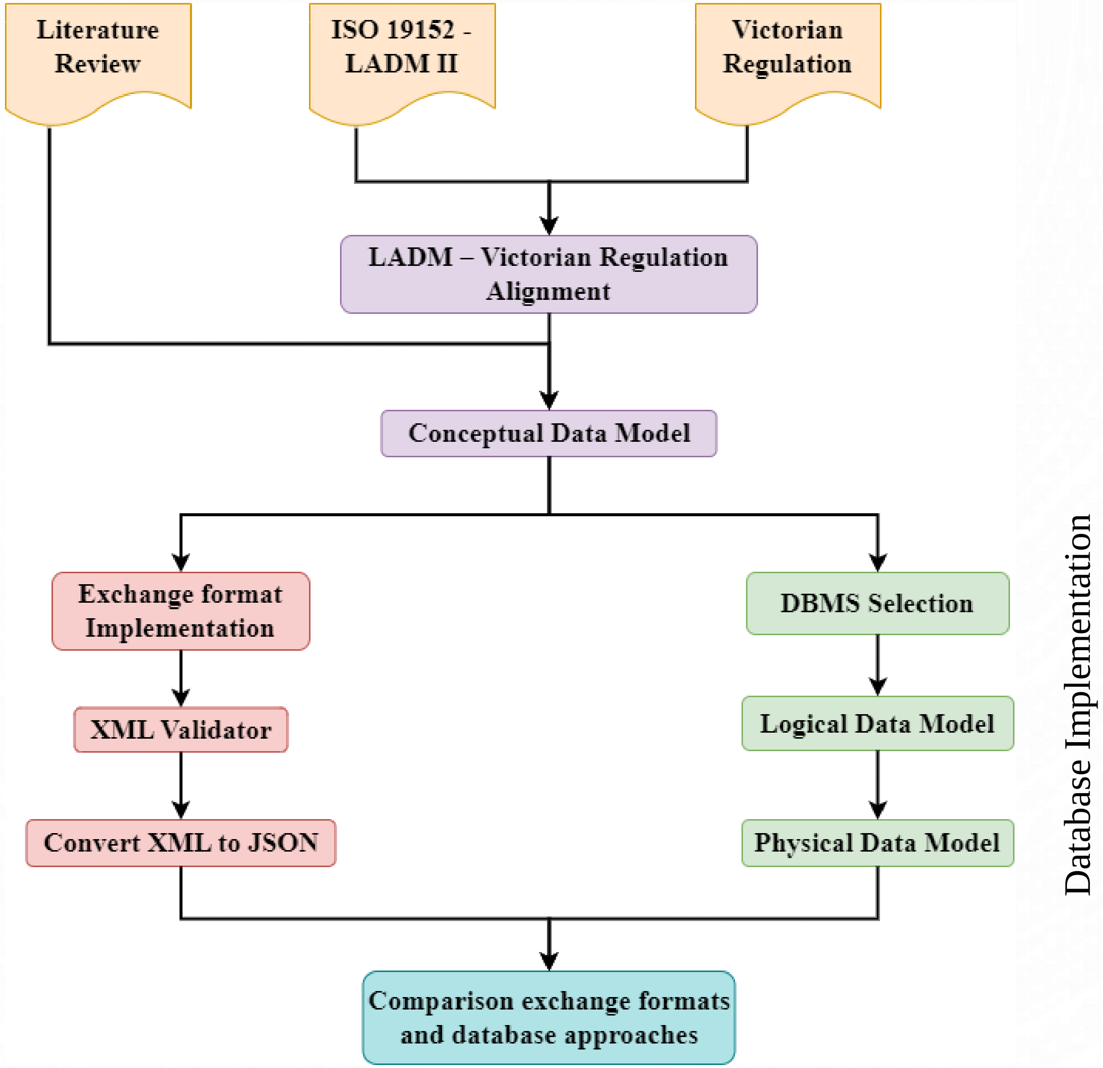
- Cadastral databases and exchange formats have been used in 2D over the past two decades.
  - Examples in Victoria/Australia include ePlan and Digital Cadastral Database (DCDB)
- Efforts are now underway to develop 3D data and exchange formats
- The Intergovernmental Committee on Surveying and Mapping (ICSM) is working on developing a 3D Cadastral Survey Data Model (3D CSDM) based on JSON format

✓ This paper aims to implement a 3D cadastral database and XML/JSON exchange formats for the Victorian cadastre, adopting LADM Edition II.

✓ The paper highlights the needs and challenges in implementation.



RESEARCH METHODOLOGY



VICTORIAN CADASTRAL SYSTEM

✓ Distributed system of **datasets**, **processes**, and **regulations**

❖ Vicmap

- Vicmap has been part of the state’s primary mapping system since 1975.
- Vicmap Catalogue includes 17 products
- **Vicmap Property** serves as Victoria’s cadastral map base
- Also known as the Digital Cadastral Database (DCDB)

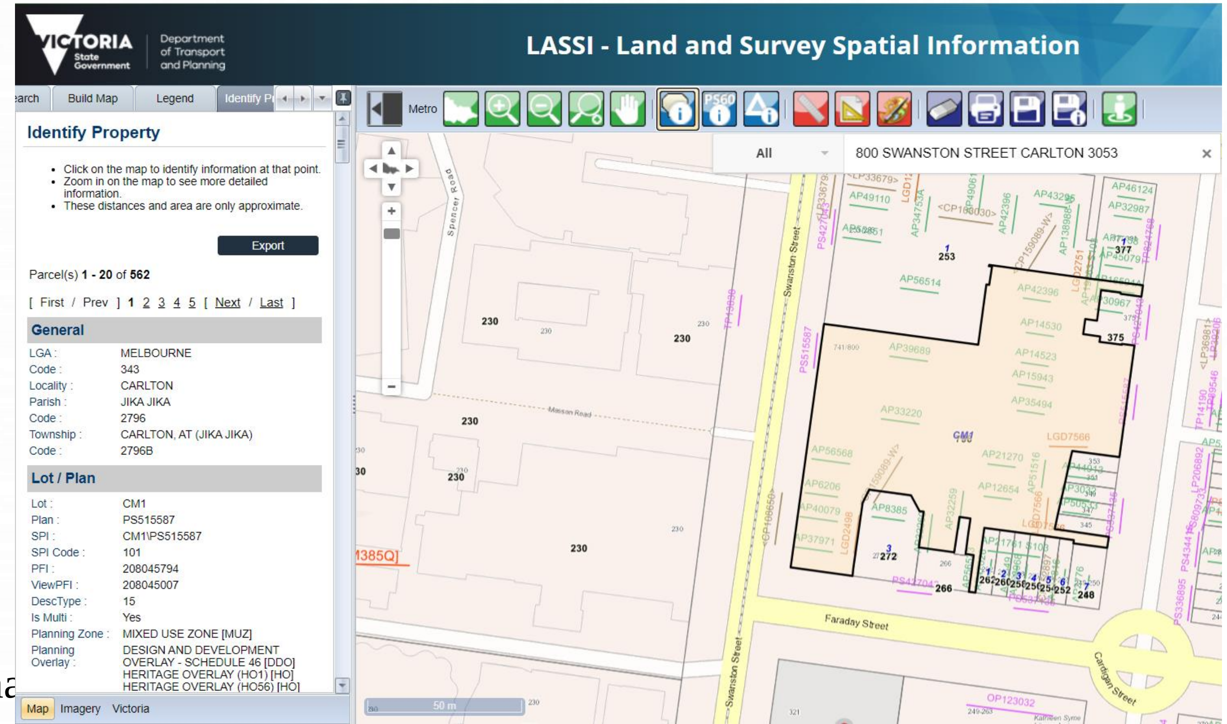
Vicmap catalogue

- Vicmap Property
- Vicmap Address
- Vicmap Admin
- Vicmap Buildings
- Vicmap Crown Land Tenure
- Vicmap Elevation
- Vicmap Feature of interest
- Vicmap Hydro
- Vicmap Planning
- Vicmap Position

VICTORIAN CADASTRAL SYSTEM

❖ Vicmap

- This database provides information on land parcels and properties, including identifiers, standard parcel identifiers (SPI), parcel status (registered or proposed), freehold and Crown land, easements, and unique feature identifiers
- **Digital Cadastre Modernisation**: a four-year $45M investment to accurately display Victorian property boundaries in a digital format.
- It is connected to **Digital Twin Victoria**



✓ Vicmap Property can be aligned with the Spatial Unit package from both Part 1 and Part 2

✓ Vicmap Address is matched with the External package (ExtAddress) of Part 1

Source: https://www.land.vic.gov.au/maps-and-spatial/spatial-data/vicma

VICTORIAN CADASTRAL SYSTEM

❖ Surveying and Planning through Electronic Applications and Referrals (SPEAR)

- SPEAR is an online system that allows subdivision planning permits, certification applications and other land administration dealings to be compiled, lodged, managed, referred, approved and tracked online.

- SPEAR is aligned with the Party and Generic Conceptual Model packages from Part 1, as well as with Part 5 – Spatial Plan Information. Also, it is aligned with the external package of the Part 2.

Source: https://www.spear.land.vic.gov.au/spear/pages/about/what-is-spear/overview.shtml

VICTORIAN CADASTRAL SYSTEM

❖ ePlan

- ePlan is a digital data file based on LandXML which represents cadastral and administrative information related to a plan

- ePlan itself is part of the SPEAR process so it is corresponded to Part 1 and Part 5.
- It includes survey measurements and parcel dimensions which is in line with Survey and Representation package of Part 2.

Source: https://www.spear.land.vic.gov.au/spear/pages/eplan/about/what-is-eplan.shtml

VICTORIAN CADASTRAL SYSTEM

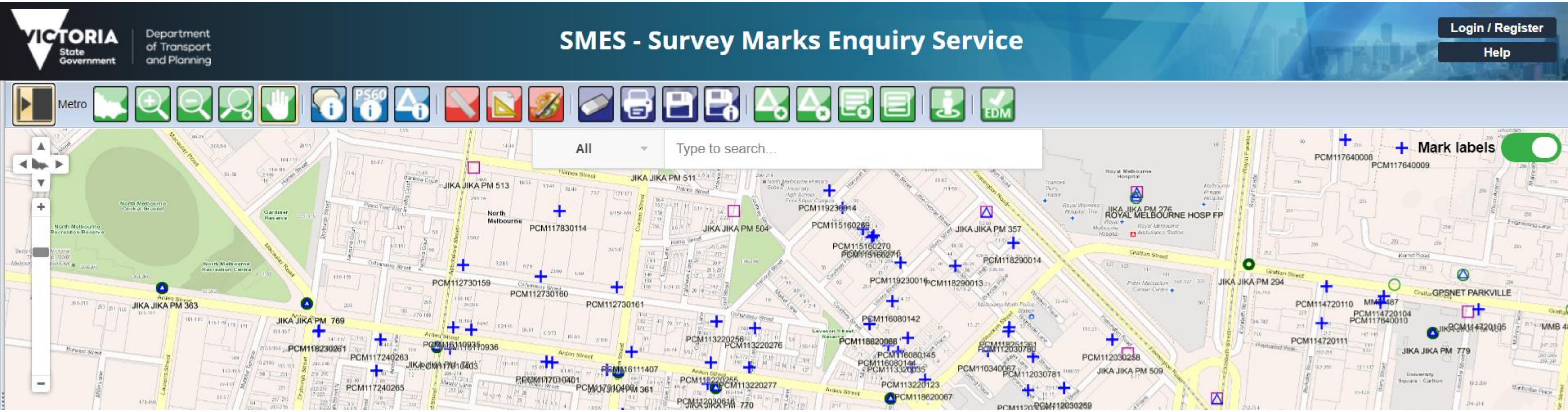
❖ Victorian Online Title System (VOTS)

- Land titles are maintained within the VOTS, a comprehensive database that serves as the authoritative record of land ownership
- VOTS is a non-spatial database that not only documents ownership details but also includes information on restrictions such as mortgages, covenants, caveats, and easements that may affect the property
- VOTS corresponds to the Administrative and Party packages in both Part 1 and Part 2. Additionally, it can be considered as a source document.

VICTORIAN CADASTRAL SYSTEM

❖ Survey Marks Enquiry Service (SMES)

- SMES is an open-access database of survey control mark information in Victoria, which can be matched to the Survey and Representation of Part 2.



Source: https://www.land.vic.gov.au/surveying/services/survey-marks-enquiry-service

VICTORIAN CADASTRAL SYSTEM

❖ Surveyors Registration Board of Victoria

- Responsible for the registration of licensed surveyors to perform cadastral surveying in Victoria and provides a database of registered licensed surveyors

✓ This aligns with the Party package in Part 1

Register of Licensed Surveyors

Order by : Surname

Show : All

505 Surveyors Found

Reg#	Name	Status	Notes	More Info
2137	Dayan Abeysekara	PRACTISING		
1984	Matthew Ackroyd	PRACTISING		
2059	David Ada	PRACTISING		
1315	Kenneth Adams	PRACTISING		
2070	Ralph Anderson	PRACTISING		
1731	Zois Aravanis	PRACTISING		
1698	Susan Argus	NON-PRACTISING		
1105	Rodney Aujard	NON-PRACTISING		
1904	Bradley Aujard	PRACTISING		

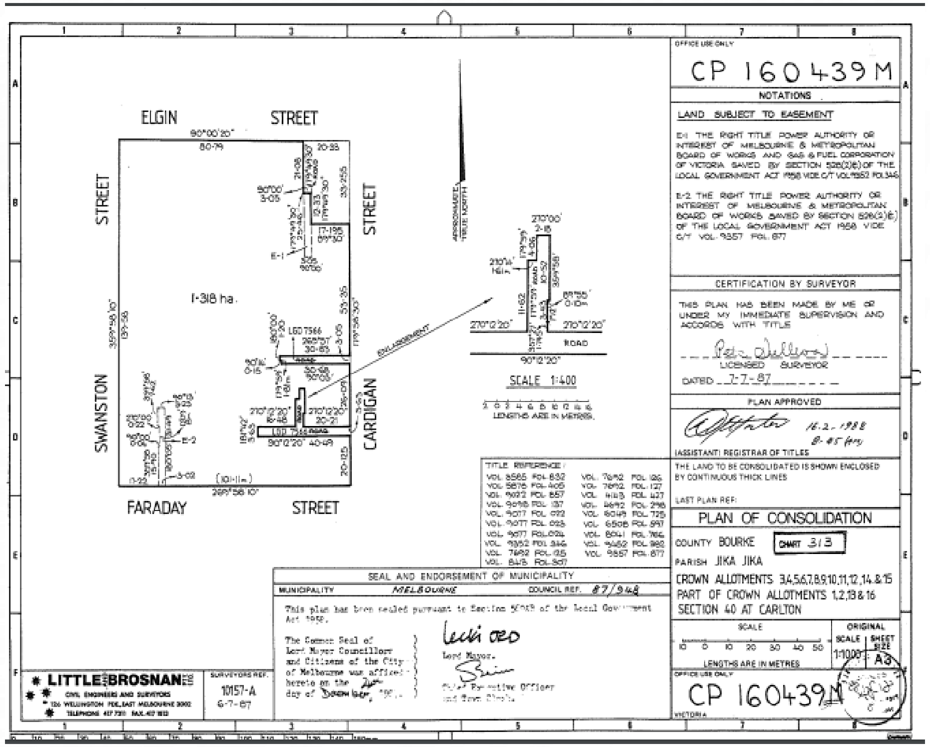
Source: https://www.surveyorsboard.vic.gov.au/

VICTORIAN CADASTRAL SYSTEM

❖ Abstract of field record

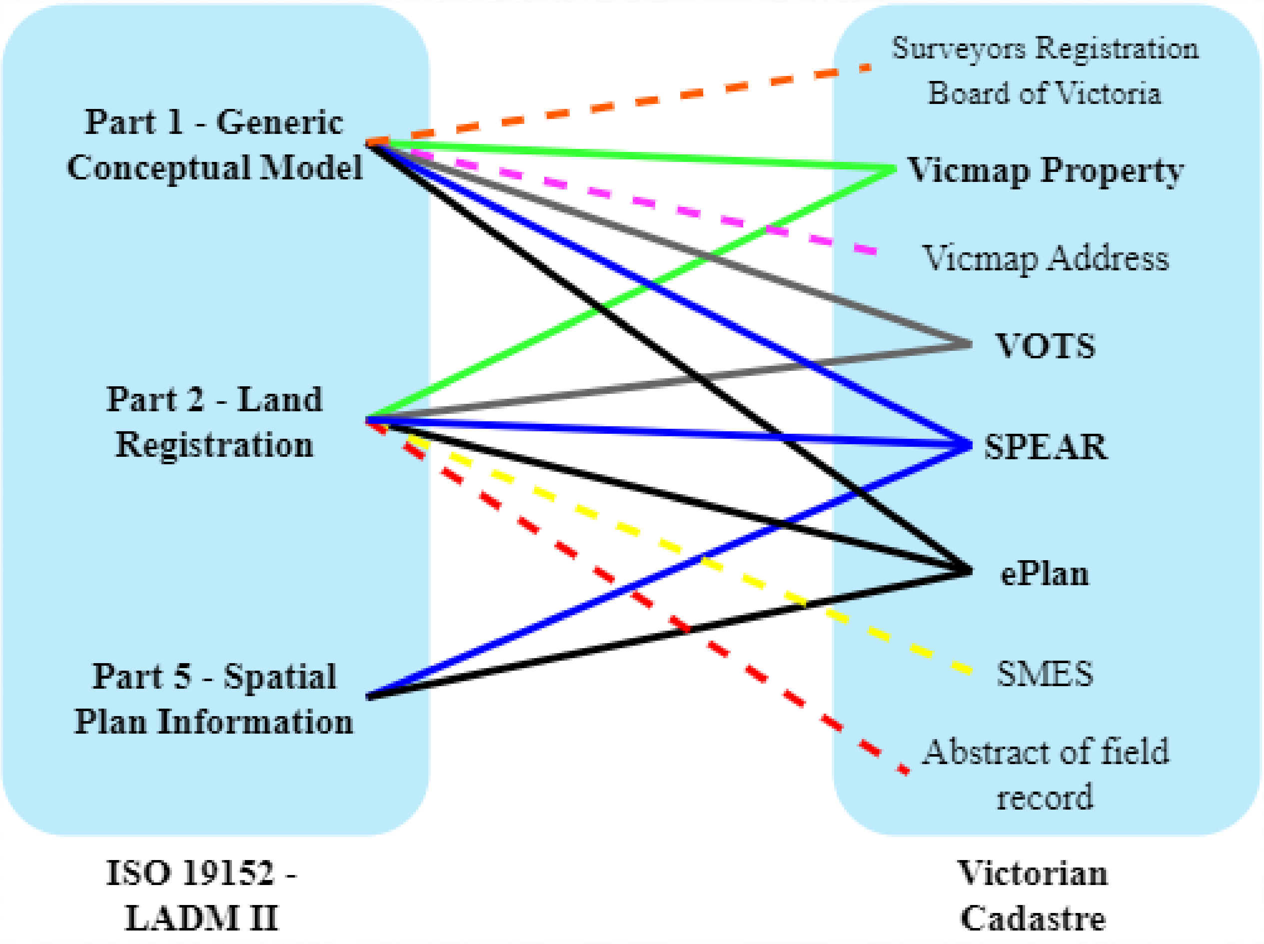
- A document containing detailed information recorded by a licensed surveyor.
- Provides documentary evidence of field conditions that support the chosen re-establishment method
- Offers supplementary information to verify recorded measurements
- Documents site conditions, such as traverse lines and instrument positions, which indicate topography and the presence of obstacles

- Aligns with the Spatial Unit package and its subpackage, Surveying and Representation, from Part 2.
- Serves as a source of survey measurements
- PDF documents need to be recorded.



Source: https://www.land.vic.gov.au/surveying/professional-resources/how-to-record-field-information
https://maps.land.vic.gov.au/lassi/SpearUI.jsp

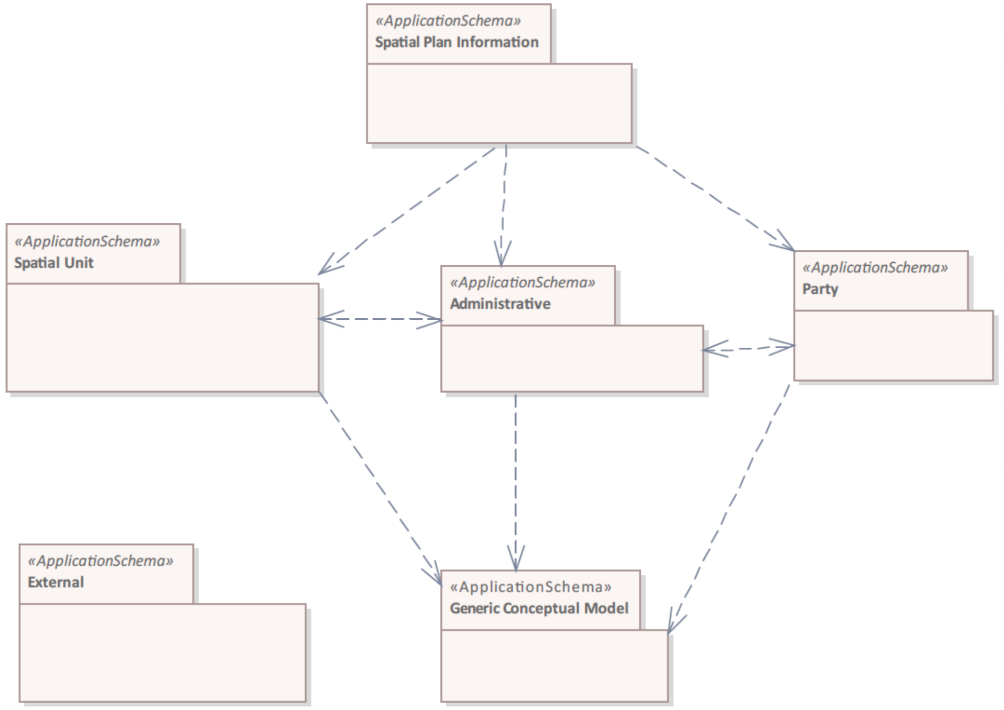
COMPLIANCE OF THE VICTORIAN CADASTRAL SYSTEM WITH LADM II



IMPLEMENTATION

❖ Conceptual data modelling

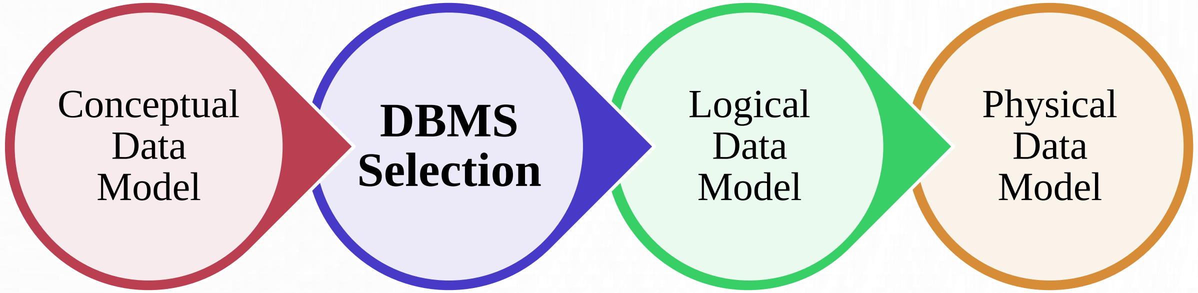
- Integration of parts 1, 2, and 5 of LADM II
- Utilising Enterprise Architect to facilitate the integration of these parts.
- Part 1 is considered the core, with additional packages added to it.
- A total of six packages are included in the integrated model.



IMPLEMENTATION

❖ Database Design

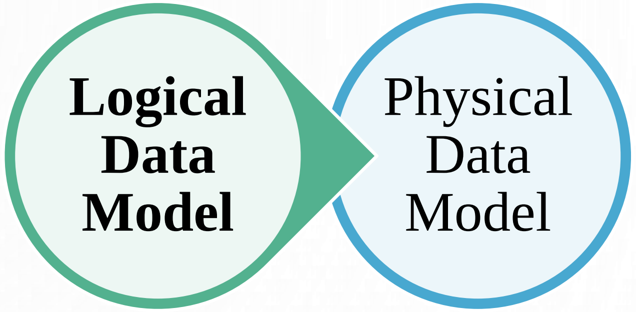
- **DBMS Selection**



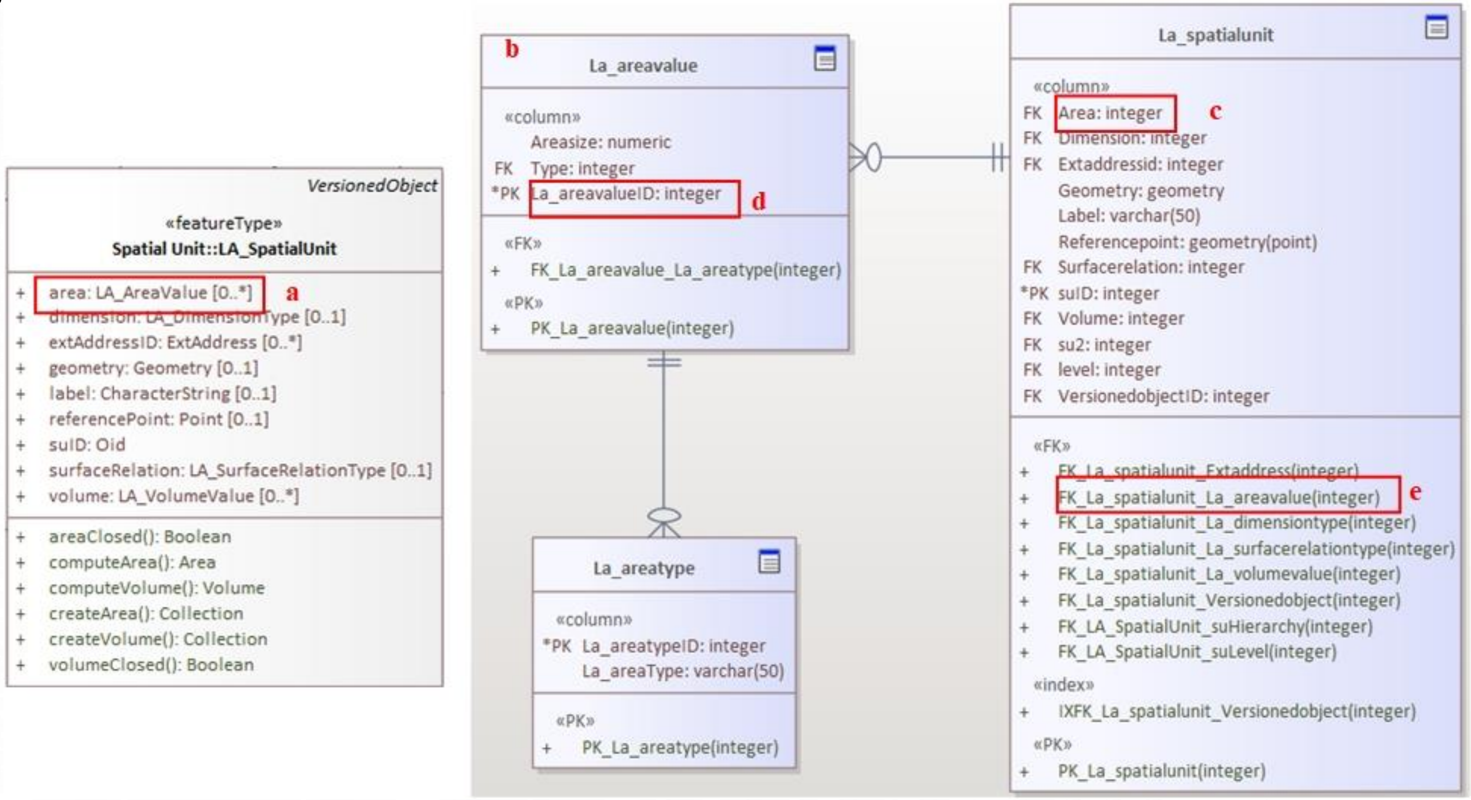
- Since cadastral data are mostly structured, a suitable option is to use relational data modelling and relational DBMSs
- PostgreSQL/PostGIS and Oracle Spatial are the two most widely used options
- PostgreSQL supports spatial applications through its PostGIS extension and is free and open-source

IMPLEMENTATION

❖ Database Design - Logical data modelling



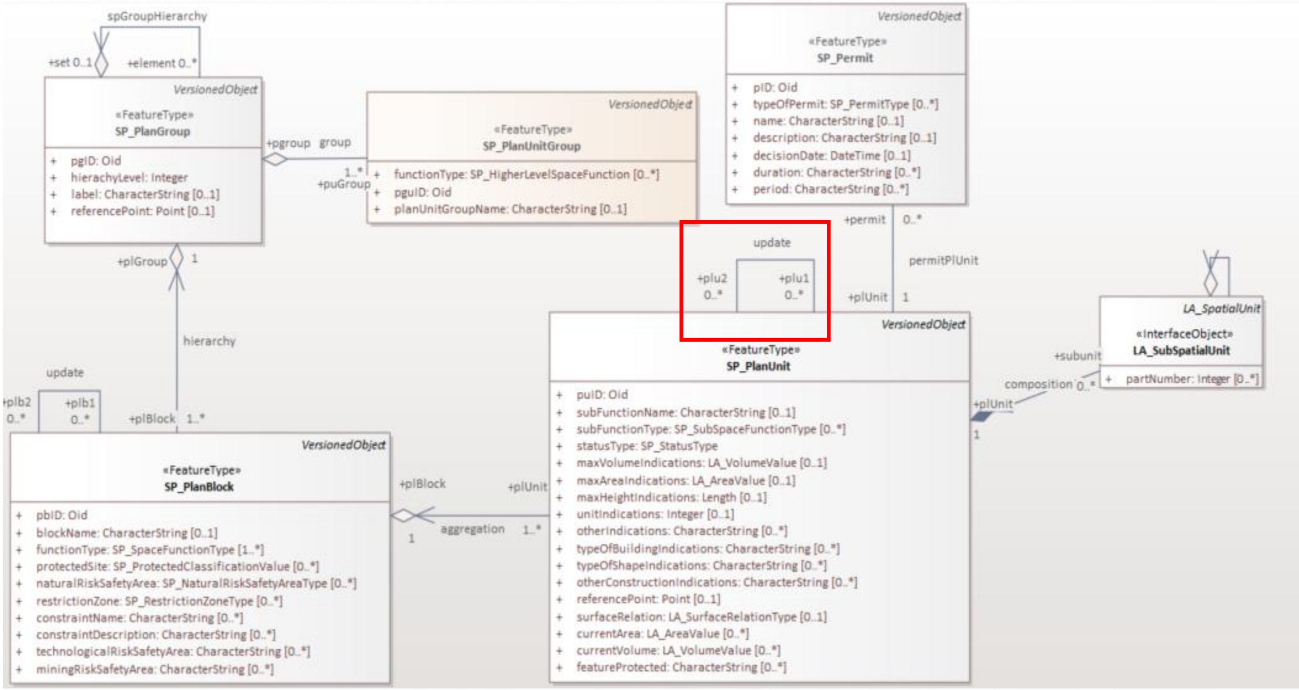
- Formalising Entities (Classes) into Relations (Tables)
- Converting Attributes to Columns/Tables
  - Multivalued Attribute (Figure)
  - Composite Attribute (extAddress)
  - Derived Attributes (computeArea)
- Primary Key (PK)

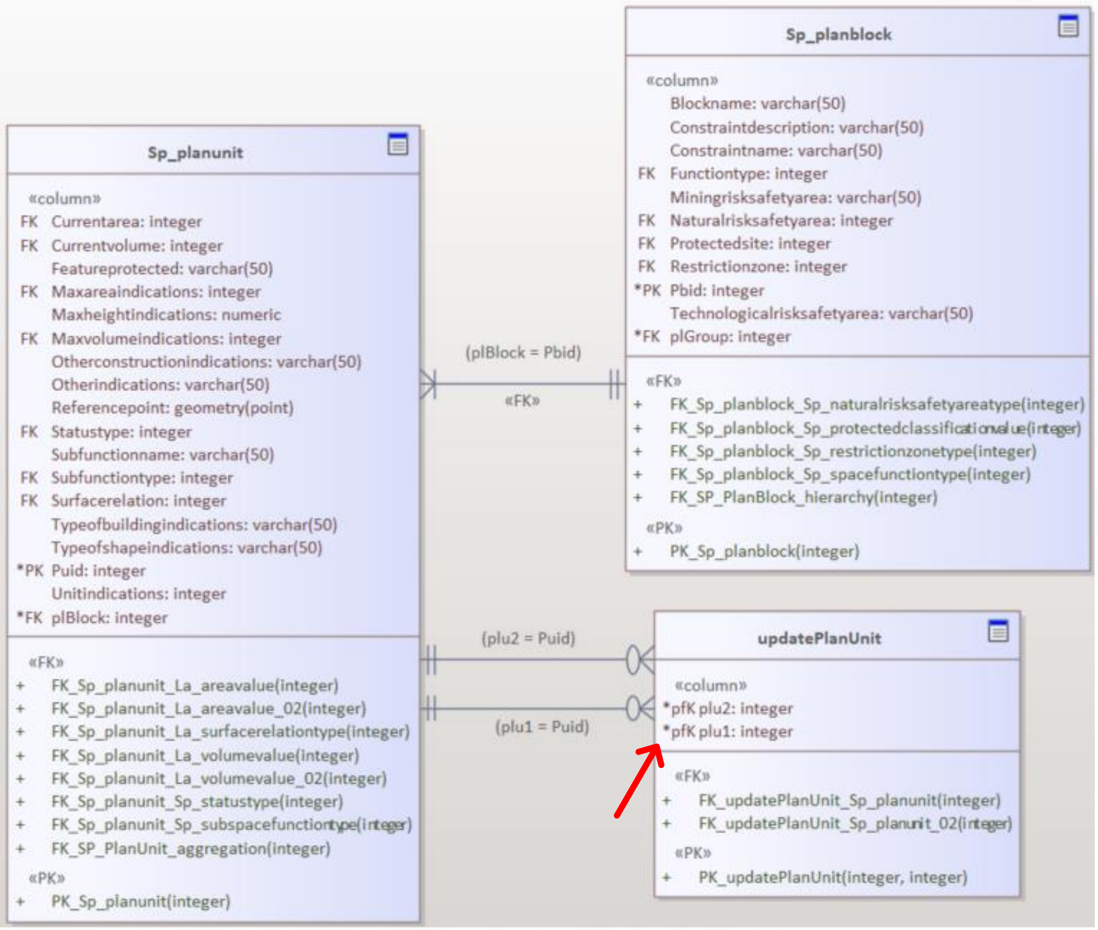


IMPLEMENTATION

❖ Database Design - Logical data modelling

- Resolve Relationships
  - 1:1 Relationships
  - 1:M Relationships
  - M:N Relationships

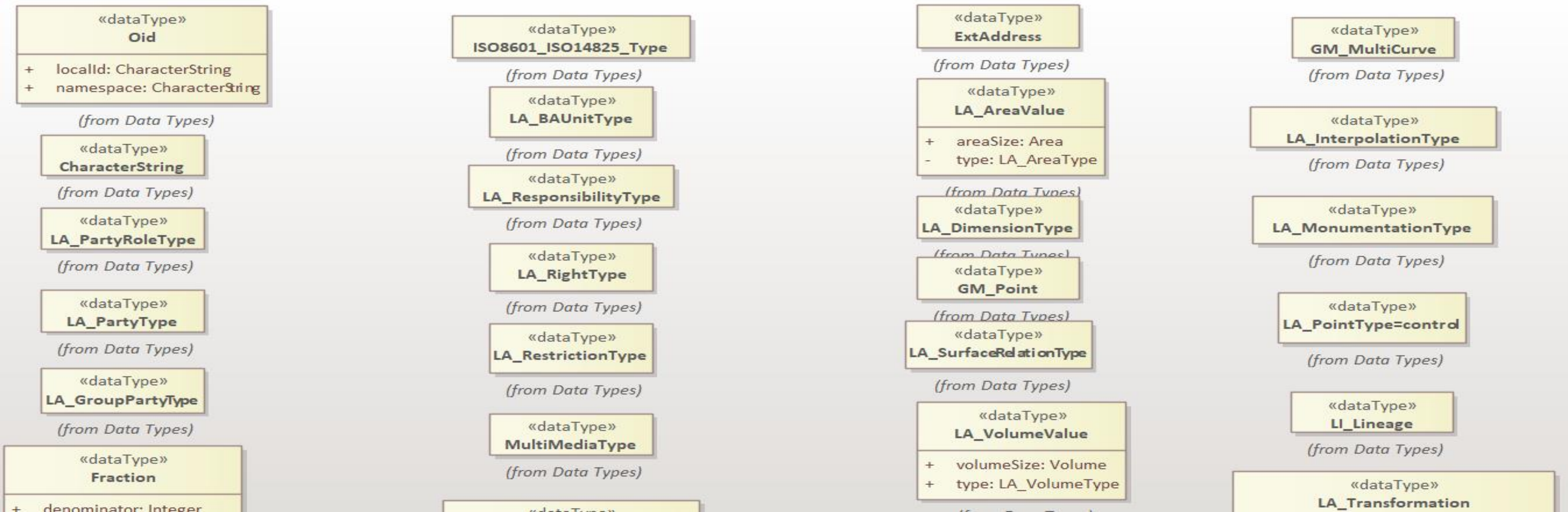




IMPLEMENTATION

❖ Database Design - Logical data modelling

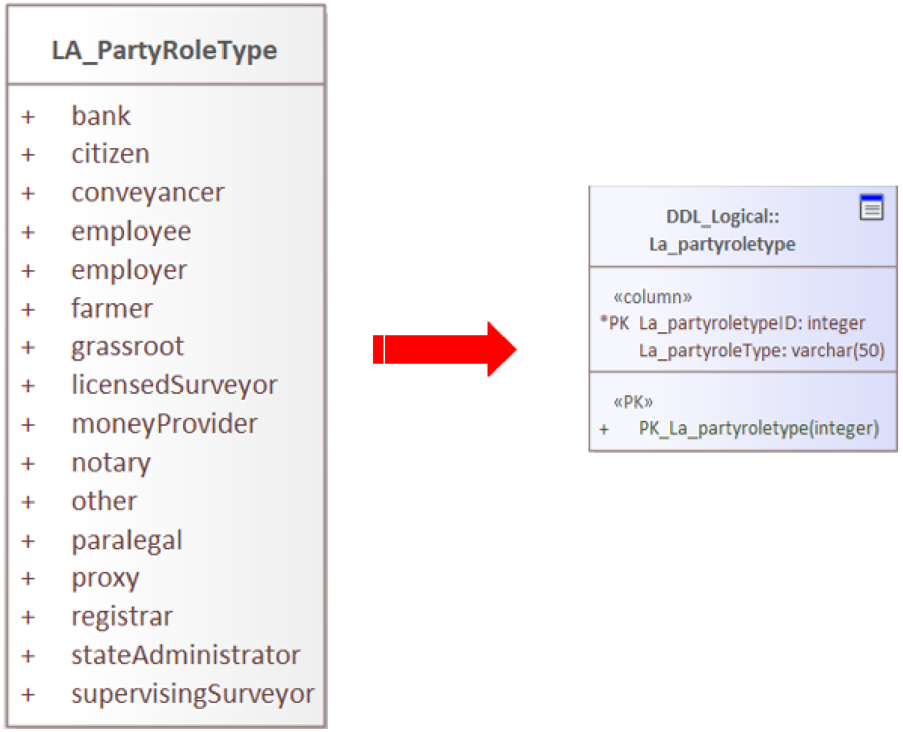
- Defined data types
- Geometry data types supported by relational databases



IMPLEMENTATION

❖ Database Design - Logical data modelling

- Domain and Code Lists
- Enum function in PostgreSQL



IMPLEMENTATION

❖ Database Design - Logical data modelling

- Inheritance/generalisation relationship
    - Single table inheritance
    - Class table inheritance
    - Concrete table inheritance
    - Object-oriented inheritance in RDBMSs

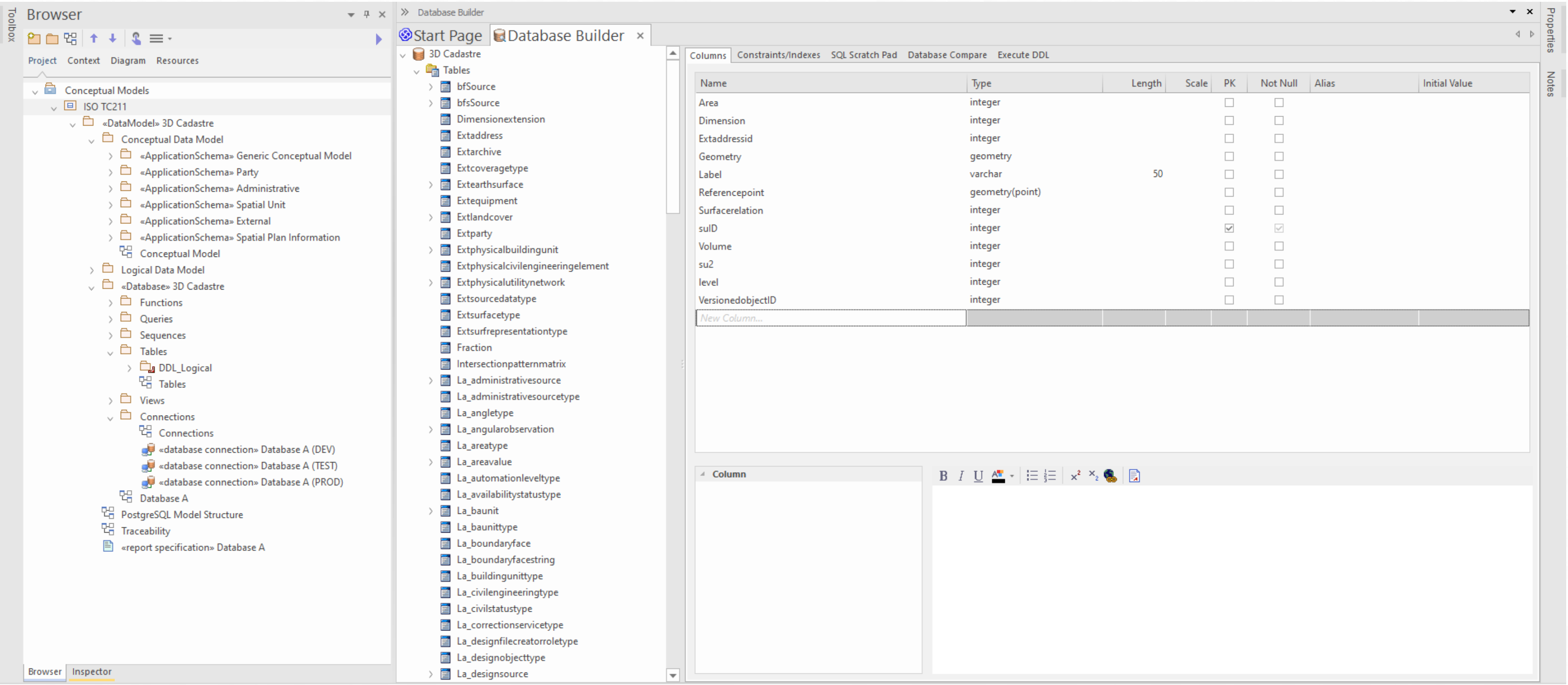
- Multiplicity / Cardinality / Participation
- Operations (Methods / Constraints)
- Normalisation
- Indexing

IMPLEMENTATION

❖ Database Design - Physical data modelling

Physical Data Model

- Generating SQL Codes
- Using Database Builder In Enterprise Architect



IMPLEMENTATION

THE UNIVERSITY OF MELBOURNE

CSDILA

❖Database Design - Physical data modelling

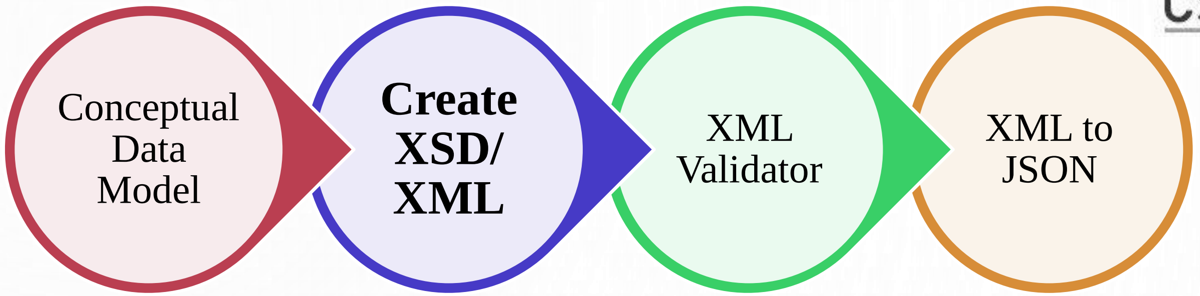
- Generating SQL Codes
- Using Database Builder In Enterprise Architect

Physical Data Model

Generating SQL Codes	Using Database Builder in EA
Advantages: • Flexibility and full control over SQL code. • Allows precise customisation and correction. • Independence from EA. • Allowing management in any DBMS.	**Advantages:** • Automates direct changes in the DBMS. • Seamless integration with DBMS for real-time updates. • Provides additional functionalities like views, functions, and queries, and user-friendly interface. • Requires no advanced database knowledge. • Integrates conceptual, logical, and physical models in a single environment.
Disadvantages • Requires manual modifications. • Time-consuming • Higher risk of human error during manual editing. • Less efficient for large projects. • Required more advanced SQL knowledge	**Disadvantages:** • Requires manual modifications. • Less control over the SQL code. • Dependency on EA. • Complex initial setup and connection process. • Requires a corporate or higher license for EA, which increases costs.

IMPLEMENTATION

- ❖ **Exchange formats Development**



- ePlan is currently stored in XML format.
- ICSM is developing a 3D conceptual data model for Australia that uses JSON as its format


```xml
<?xml  version='1.0' encoding='utf-8' ?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
    <xs:element name="bfSource" type="bfSource"/>
    <xs:complexType name="bfSource">
        <xs:sequence>
            <xs:element name="bf" type="xs:integer" minOccurs="1" maxOccurs="1"/>
            <xs:element name="source" type="xs:integer" minOccurs="1" maxOccurs="1"/>
            <xs:element name="PK_La_boundaryface" type="La_boundaryface" minOccurs="1" maxOccurs="1"/>
            <xs:element name="PK_La_spatialsource" type="La_spatialsource" minOccurs="1" maxOccurs="1"/>
        </xs:sequence>
    </xs:complexType>
    <xs:element name="bfsSource" type="bfsSource"/>
    <xs:complexType name="bfsSource">
        <xs:sequence>
            <xs:element name="bfs" type="xs:integer" minOccurs="1" maxOccurs="1"/>
            <xs:element name="source" type="xs:integer" minOccurs="1" maxOccurs="1"/>
            <xs:element name="PK_La_boundaryfacestring" type="La_boundaryfacestring" minOccurs="1" maxOccurs="1"/>
            <xs:element name="PK_La_spatialsource" type="La_spatialsource" minOccurs="1" maxOccurs="1"/>
        </xs:sequence>
    </xs:complexType>
    <xs:element name="Dimensionextension" type="Dimensionextension"/>
    <xs:complexType name="Dimensionextension">
        <xs:annotation>
            <xs:documentation>The dimension extension type of topology, see ISO 19107:2019</xs:documentation>
        </xs:annotation>
        <xs:sequence>
            <xs:element name="DimensionextensionID" type="xs:integer" minOccurs="1" maxOccurs="1"/>
            <xs:element name="DimensionextensionType" type="xs:string" minOccurs="1" maxOccurs="1"/>
        </xs:sequence>
```



```json
{
  "schema": {
    "element": [
      {
        "_name": "bfSource",
        "_type": "bfSource",
        "__prefix": "xs"
      },
      {
        "_name": "bfsSource",
        "_type": "bfsSource",
        "__prefix": "xs"
      },
      {
        "_name": "Dimensionextension",
        "_type": "Dimensionextension",
        "__prefix": "xs"
      },
      {
        "_name": "Extaddress",
        "_type": "Extaddress",
        "__prefix": "xs"
      },
      {
        "_name": "Extarchive",
        "_type": "Extarchive",
        "__prefix": "xs"
      },
      {
        "_name": "Extcoveragetype",
        "_type": "Extcoveragetype",
        "__prefix": "xs"
      },
      {
        "_name": "Extearthsurface",
        "_type": "Extearthsurface",
        "__prefix": "xs"
      },
```

DISCUSSION

Criteria	Database Schema	Exchange Format Schema (XML, JSON)
Conceptual Model	Both methods share the same conceptual model, ensuring consistency at the conceptual level.	Both methods share the same conceptual model, ensuring consistency at the conceptual level.
User Interface and Ease of Use	Comes with a user-friendly interface that allows easy access and editing of tabular data.	Lacks a native user interface; requires external tools for editing and manipulation
Data Entry	Can be performed manually or automatically using SQL commands or a database interface. Manual entry of geometrical data is particularly challenging.	More challenging without specialised tools; External tools or XML editors are often needed to manage data entry efficiently.
Semantic and Linked Data	Limited. Traditional relational databases are not inherently designed for semantic data or linked data, but they can be extended to support semantic structure. Some DBMSs, such as Oracle, support semantic technologies. Additionally, there are triple stores that support RDF; however, it is necessary to investigate whether they also support 3D spatial data.	XML is naturally compatible with RDF and other semantic web standards. It is easier to convert XML to RDF or import XML to platforms that support semantic formats.
Integrity	Strong data integrity with enforced integrity constraints.	Weaker data integrity.
Flexibility	Changes to schema can be complex, because of constraints	Schemas can be modified more easily

DISCUSSION

❖ Conceptual data model integration

- Each of the LADM parts is a standalone standard
- A key challenge is duplication at schema level and integrating these packages while maintaining consistency and integrity
- We used part 1 as the core framework. The relevant packages and classes from parts 2 and 5 were manually incorporated, preserving their full structure

❖ Challenges in converting conceptual data model into logical data model

- There is no fully automated method for this conversion and many steps still need to be done manually

❖ Linked data and semantic consistency

- Database tables are not linked to the evolving LADM terminology
- This can lead to potential inconsistencies or need ongoing updates and alignments
- Adoption of linked data, ontology, and semantic web principles could enhance semantic consistency, interoperability, and data integration

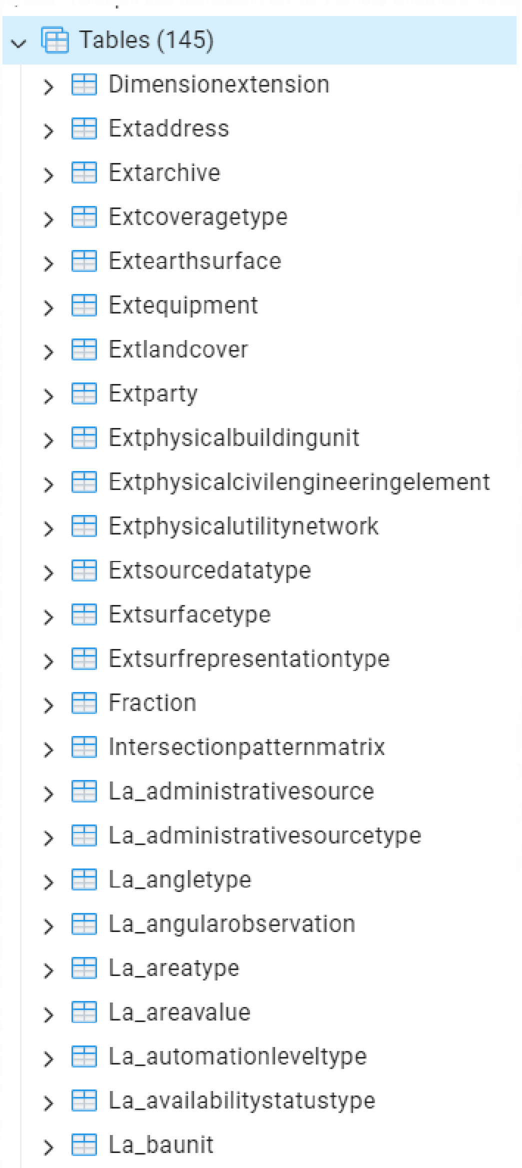
DISCUSSION

❖ Distributed Cadastral Systems in Victoria

- Cadastre is highly distributed across various projects, departments, and agencies
- Challenge lies in connecting these disparate systems, especially since there is no centralised database
- An alternative solution is to use the unique identifier in each system

❖ Optimisation (schema and Query)

- Lack of emphasis on database optimisation strategies.
- Creating separate tables for code lists increases the total number of tables.
- This results in more frequent use of JOIN functions in queries.
- Frequent JOIN operations can negatively impact database performance.



CONCLUSIONS

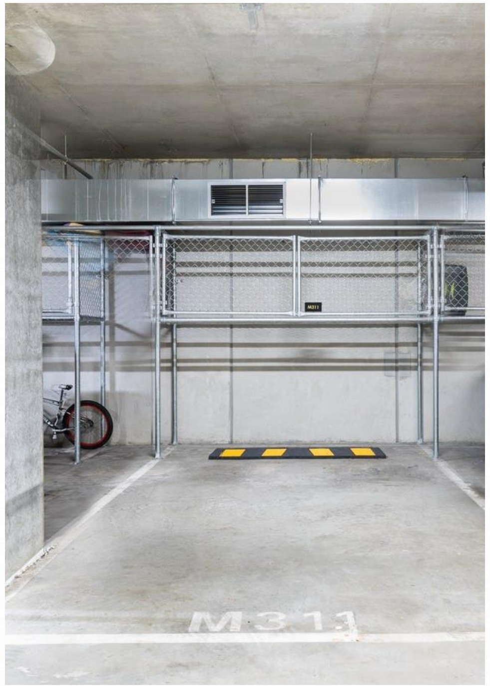
- To implement LADM for each jurisdiction, it's necessary to first identify all relevant departments and projects, then align these departments and projects with LADM II parts.
- LADM II, particularly Parts 1, 2, and 5, shows some compliance with Victorian cadastral systems.
- Two approaches for creating a physical data model in Enterprise Architect: Database Builder and generating SQL codes. Neither approach is fully automated, and manual steps are still required.
- Existing research on 3D cadastral databases focuses primarily on data storage, with limited attention to database design.

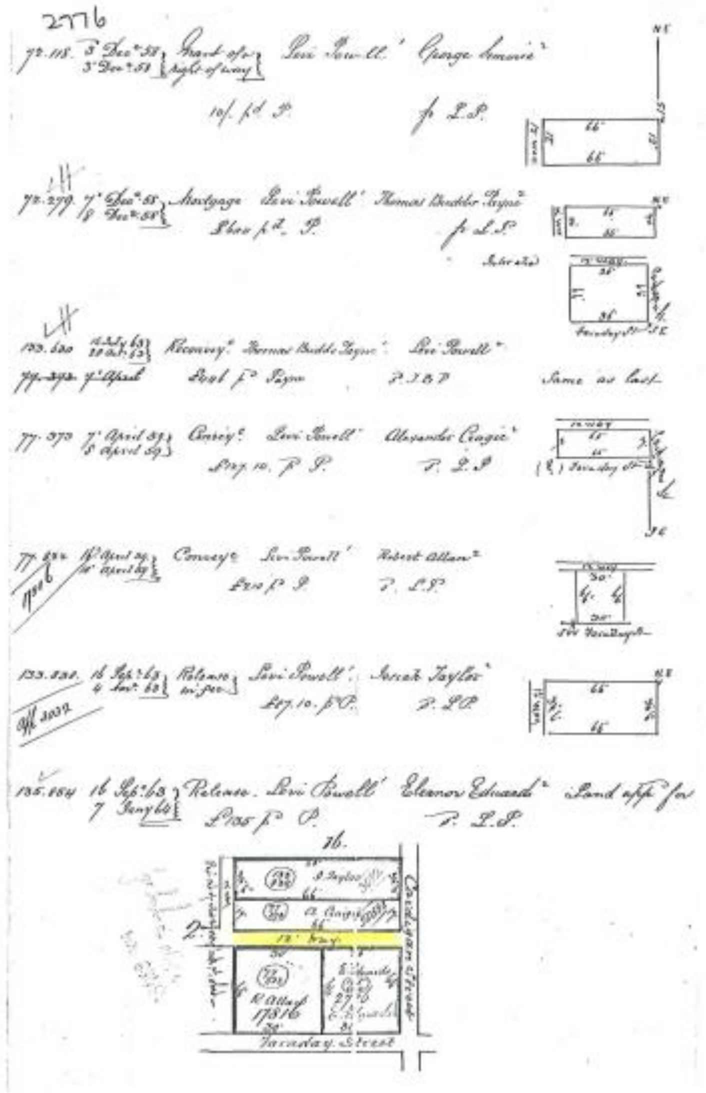
FUTURE WORKS

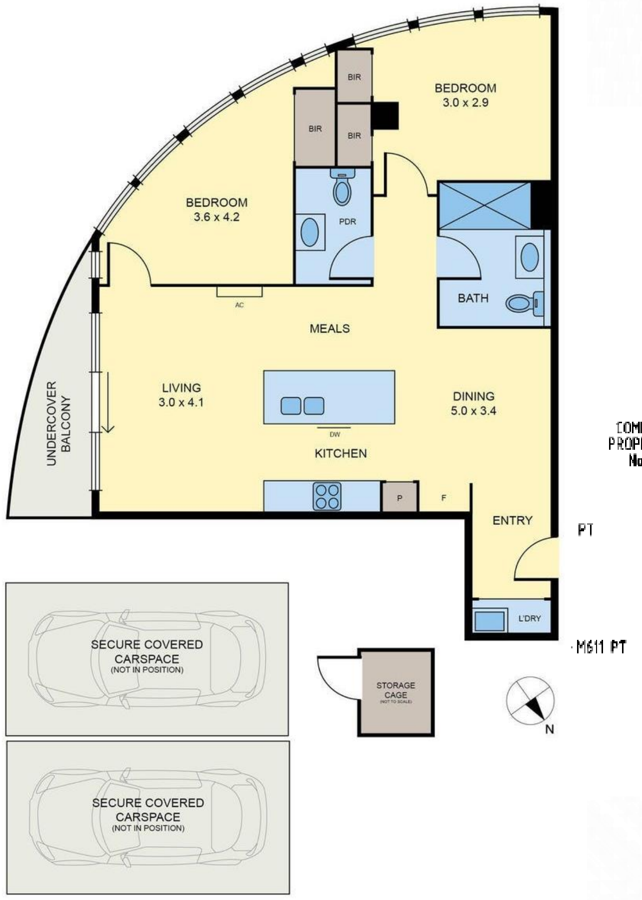
- Customising LADM II Parts 1, 2, and 5 based on the Victorian cadastral system.
- Fully populating relevant tables to evaluate database performance and efficiency at the instance level.
- Considering Query optimisation methods
- Gap in automatically converting conceptual data models into logical and physical data models.
- Use of linked data and semantic web technologies to connect different conceptual data models more effectively.
- Storing file formats in both relational and document databases (NoSQL databases), followed by a comparison of results, requires further exploration.

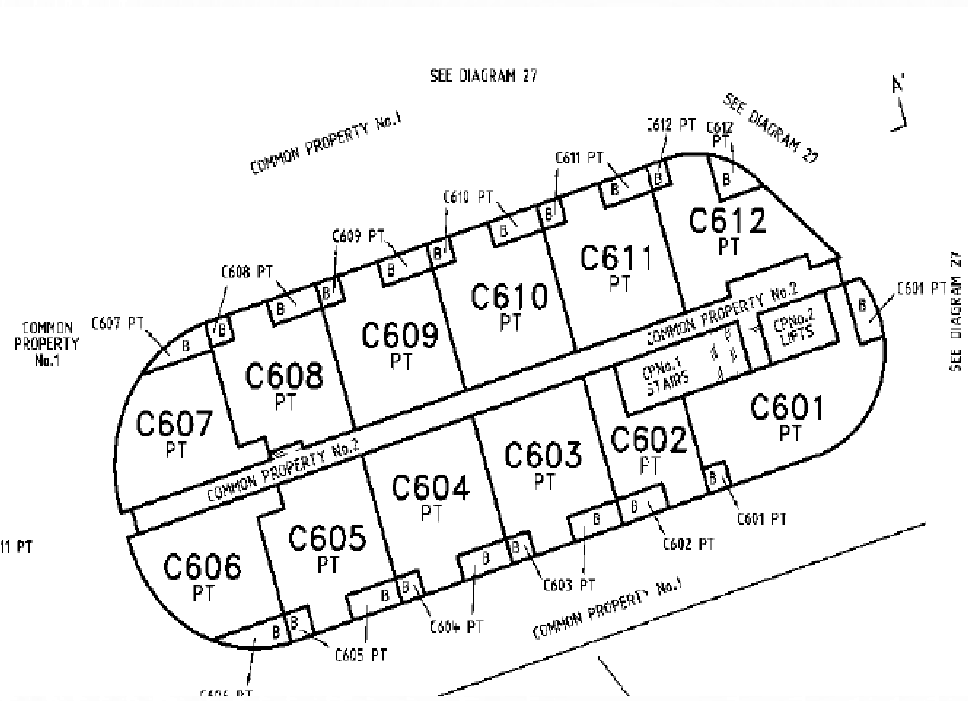
FUTURE WORKS

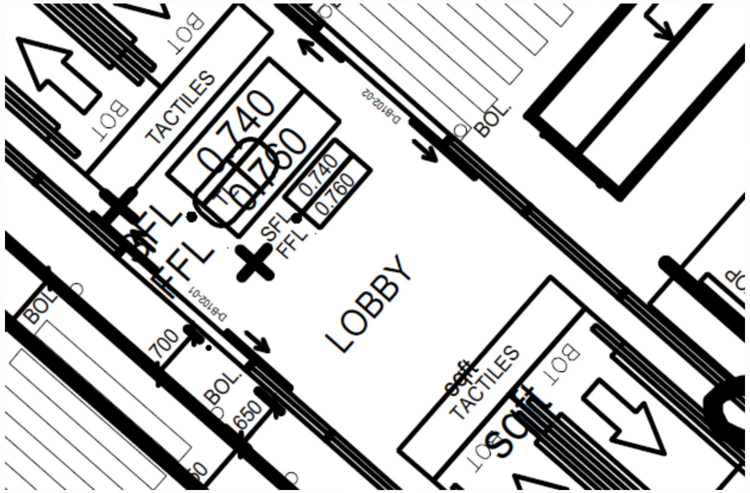
- Solving challenges in 3D data preparation
- Issues in considering Height
- Differences between Plans and the Real World
- Determining boundaries of Storage Areas and Parking
- Converting surveyor reports to database
  - Challenges with illegible handwriting
  - Issues with Low-Quality Images











SFL: Structural Floor Level

FFL: Finish Floor Level

Questions?

Suggestions?

Javad.Shahidinejad@student.unimelb.edu.au